DEVELOPMENT OF GLOBAL POSITIONING SYSTEM PREDICTION TOOLS TO SUPPORT FLIGHT PLANNING

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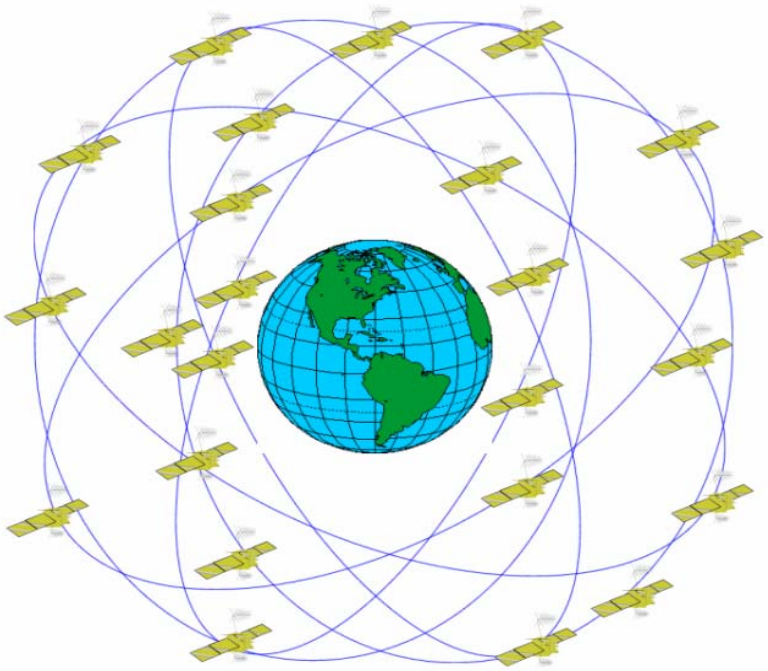
Research and Special Programs Administration



Jon Parmet, Jayne Rossetti, Karen Van Dyke DOT/Volpe Center

April 29, 2004

Outline

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- Overview
- Existing GPS Prediction Systems
- WAAS Outage Prediction System
- Challenges
- Future Direction

GPS Outages – How Do You Report?

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- GPS is Different From Ground-Based Navaids
  - Impact of Satellites Out of Service Not Intuitively Known
  - Areas of Degraded Coverage Not Stationary
- Pilots/ATC Need to Know Where and When GPS is Not Available
- A Predictive Coverage Model is Required
  - Needs to Incorporate Status, GPS SVs, WAAS/LAAS Assets, and Airfield Database

GPS Outage Prediction System - Deployments

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- Joint FAA/Air Force RAIM Prediction System Deployed in 1995
- Australian RAIM Prediction System Deployed for AirServices Australia (ASA) in 1998
- German RAIM Prediction System Deployed for Deutsche Flugsicherung (DFS) in 1998
- AUGUR Prediction Tool Deployed by EUROCONTROL in 1998
- WAAS (LNAV only) Graphical Prediction System Deployed as Prototype for Capstone Project in 2003
- WAAS (LNAV, LNAV/VNAV, LPV) Prediction System Deployed for FAA in 2003

U.S. GPS RAIM Prediction System

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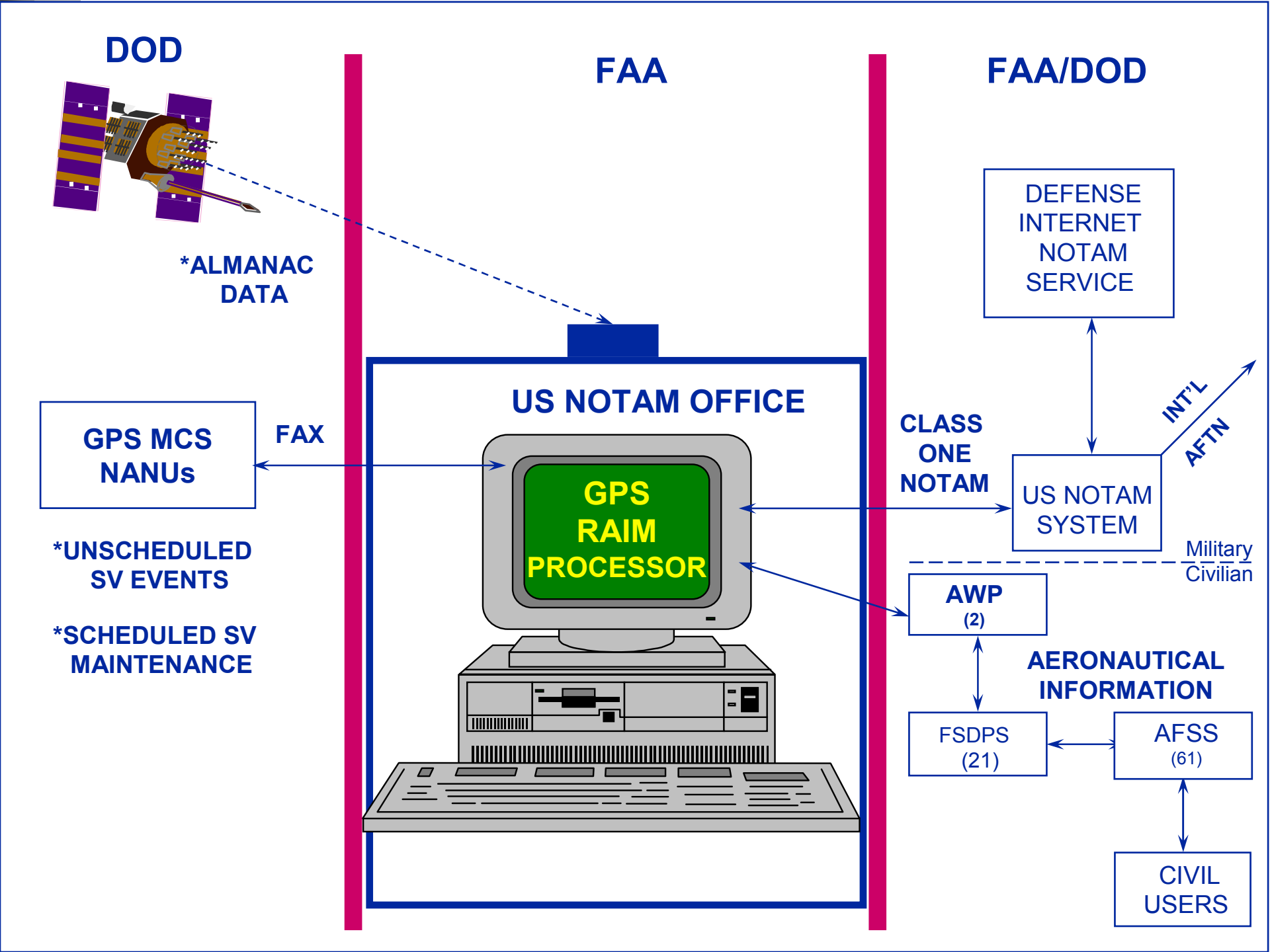
- GPS System Declared IOC in late 1993
- Joint FAA /Air Force RAIM Prediction System Deployed in 1995

- Receives GPS Satellite Outages from GPS Master Control Station

- Issues Domestic and International GPS SV NOTAMs

- NPA RAIM Outages Available to Military Pilots as M-Series NOTAMs

- NPA RAIM Outages Available to Civilian Pilots as Aeronautical Information from Flight Service Stations


DOD
FAA
FAA/DOD
*ALMANAC DATA
DEFENSE INTERNET NOTAM SERVICE
US NOTAM OFFICE
GPS MCS NANUs
FAX
GPS RAIM PROCESSOR
CLASS ONE NOTAM
US NOTAM SYSTEM
INT'L
AFTN
Military
Civilian
*UNSCHEDULED SV EVENTS
*SCHEDULED SV MAINTENANCE
AWP (2)
AERONAUTICAL INFORMATION
FSDPS (21)
AFSS (61)
CIVIL USERS

Australian GPS RAIM Outage Prediction System

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- Australian RAIM Prediction System Deployed for AirServices Australia (ASA) in 1998
- NPA RAIM Outages reported for Southern Pacific region (Australia, New Zealand, Fiji) and select locations within Canada.
- Available to pilots via National Aeronautical Information Processing System (NAIPS) briefing tool or by using Faxback (AvFAX) capability.
- Also available on the Web at:

<http://www.airservicesaustralia.gov.au>

Airservices Australia Web Site

Australian GPS RAIM Briefing Selection

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German GPS RAIM Outage Prediction System

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- German RAIM Prediction System Deployed for Deutsche Flugsicherung (DFS) in 1998
- NPA RAIM Outages reported for European region (Germany and select partners).
- German locations available as NOTAMs.
- Also available on the Web at:

<http://www/dfs.de>

- "International" locations sent to respective host country via Aeronautical Fixed Telecommunications Network (AFTN). Information not sent as NOTAM but as "outage information" due to regulations regarding NOTAMs.

DFS Deutsche Flugsicherung Web Site

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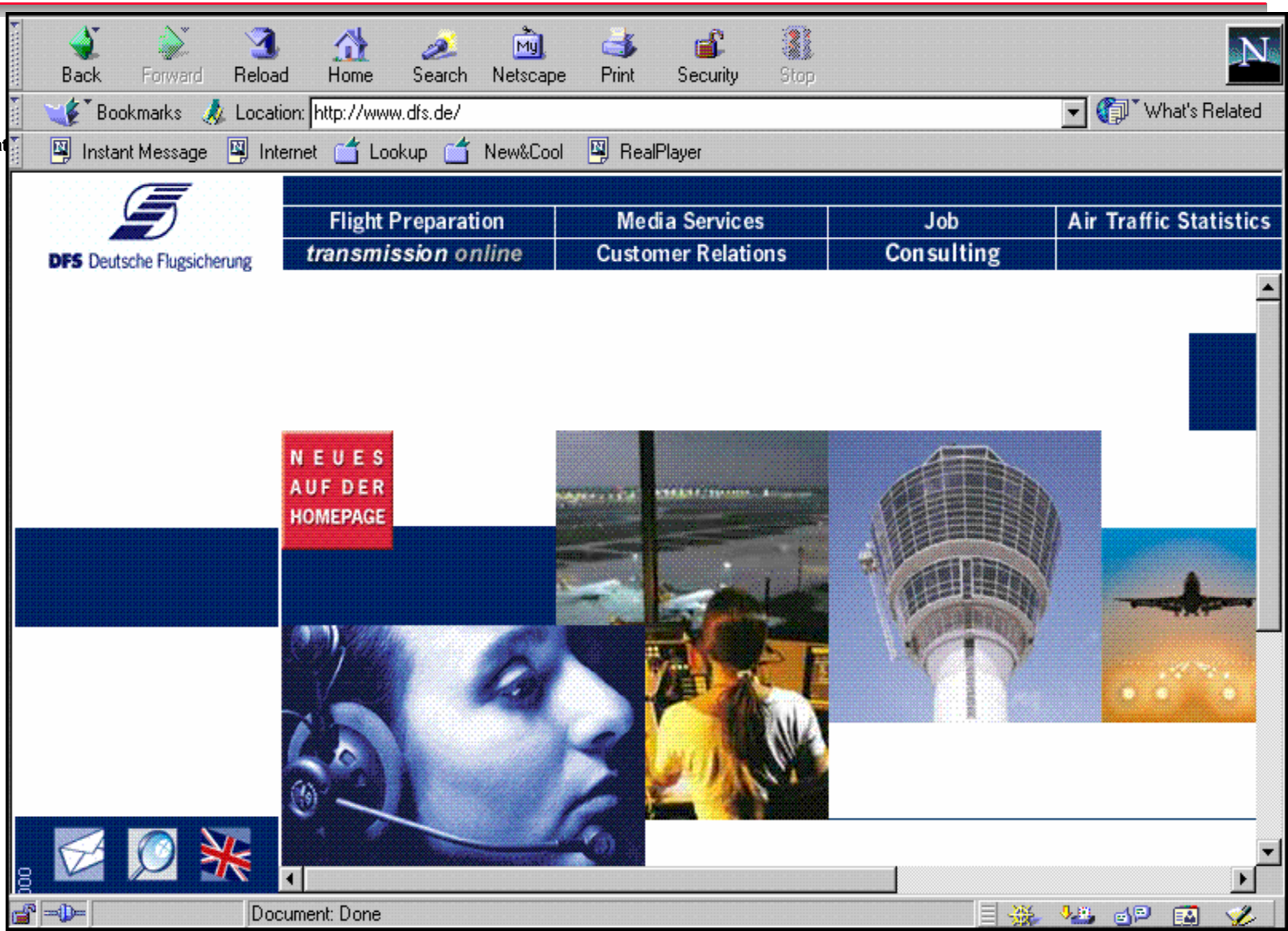

GPS RAIM Briefing

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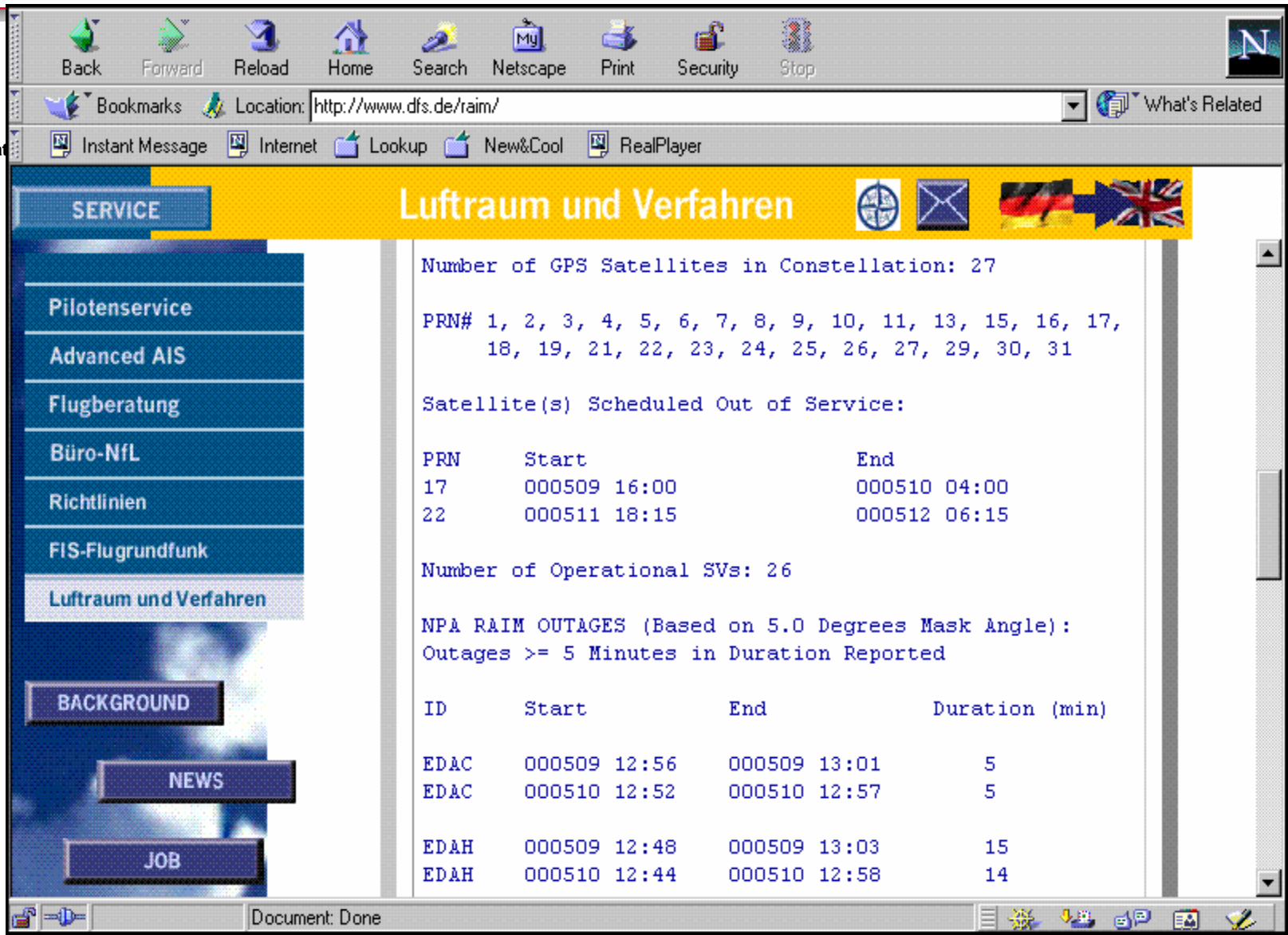

Alaska Capstone Outage Reporting System

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- WAAS Graphical Prediction System Deployed as a Prototype for FAA Capstone Project in March 2003
  - Integration of Software onto NAS Aeronautical Information Management Enterprise System (NAIMES) Platform at FAA Command Center
  - Outage information available via web-based interactive GIS at:

<https://www.waasaps.naimes.faa.gov/Capstone/>

Capstone Outage Reporting System Web Site

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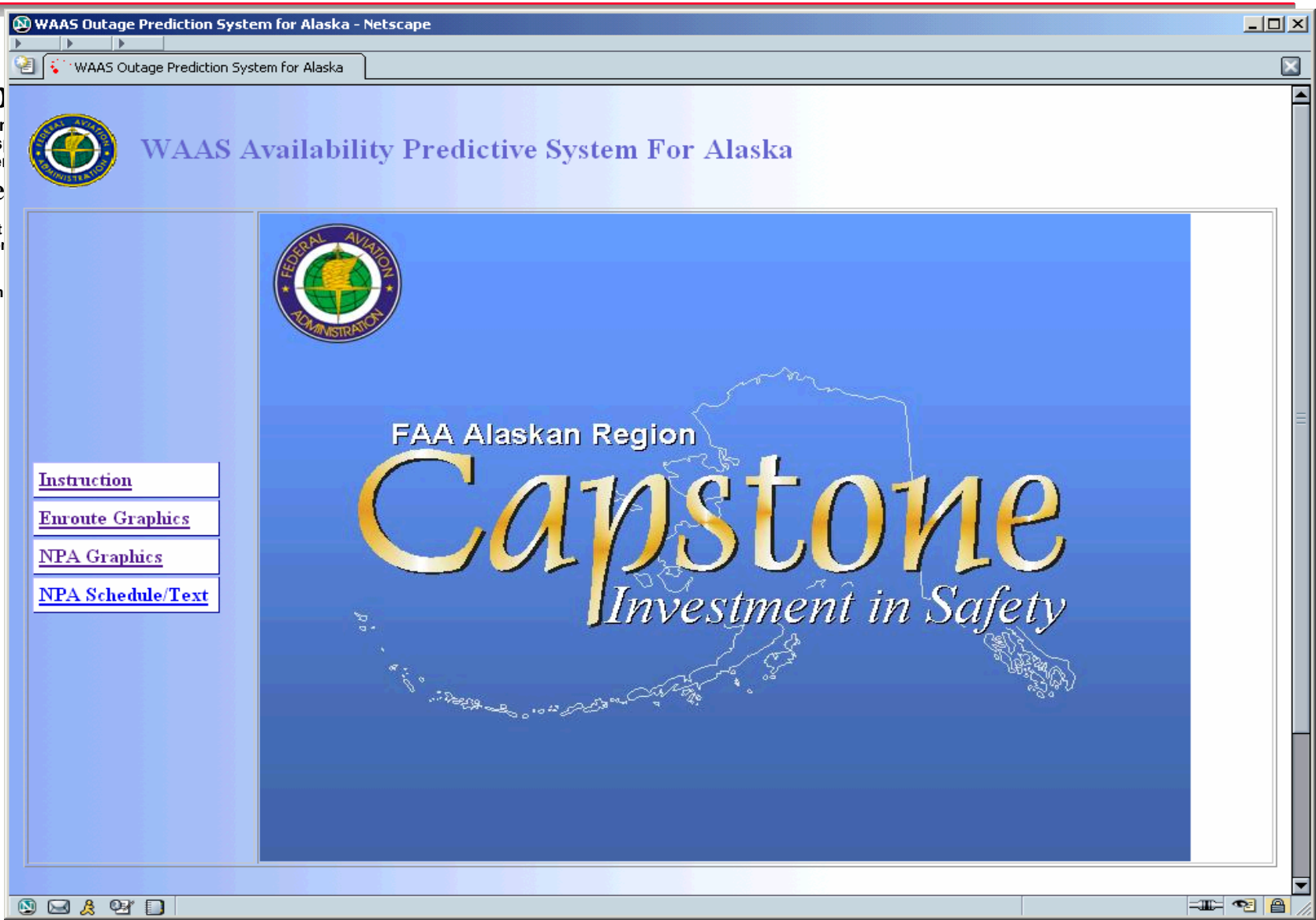

Capstone Web Site – NPA Availability Display

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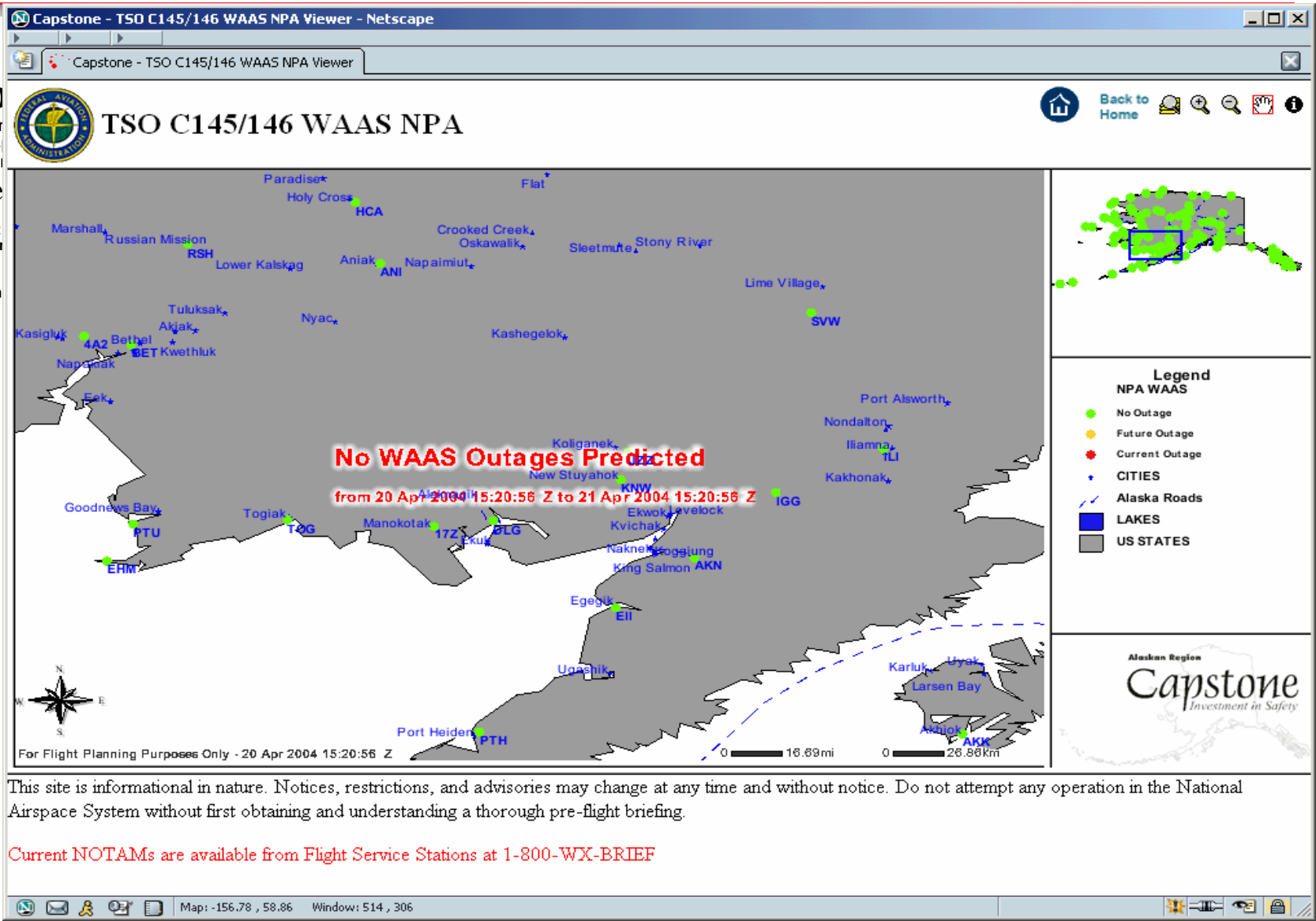

This site is informational in nature. Notices, restrictions, and advisories may change at any time and without notice. Do not attempt any operation in the National Airspace System without first obtaining and understanding a thorough pre-flight briefing.

Current NOTAMs are available from Flight Service Stations at 1-800-WX-BRIEF

FAA WAAS Outage Prediction System

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- WAAS Prediction System Deployed for FAA at WAAS IOC in July 2003
  - Integration of Software onto Solaris Platform located at FAA Command Center
  - Incorporates WAAS Asset Data (Geostationary SVs, Reference Stations, etc.)
  - Area-Wide Outages sent as NOTAMs Directly to United States NOTAM System (USNS).
  - Airfield-Specific Outages sent to Flight Service Stations in NOTAM Format. FSSs Issues NOTAMs to USNS.

WAAS Outage Prediction

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- Computes WAAS HPL and VPL for each location (grid point or airfield) once per day for the following 30 hours
  - Algorithm Based on TSO C145/146 Receiver Criteria
  - Data Calculated At One-Minute Intervals
  - Automatically Re-Computed Based on an Unexpected Change in WAAS/GPS Status.
- Reverts to Computing RAIM (LNAV only) if WAAS is Unavailable
- Determines if Protection Level(s) Exceed Alert Limit(s)
- Determine if the Outage Duration is Greater than the Minimum Reportable Outage Time, i.e. Whether a NOTAM Should be Issued

WAAS Outage Prediction

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- **En Route Predictions**
  - Computed for Set of Grid Points at 1 Min.Time Intervals
  - Determine if HPL>HAL

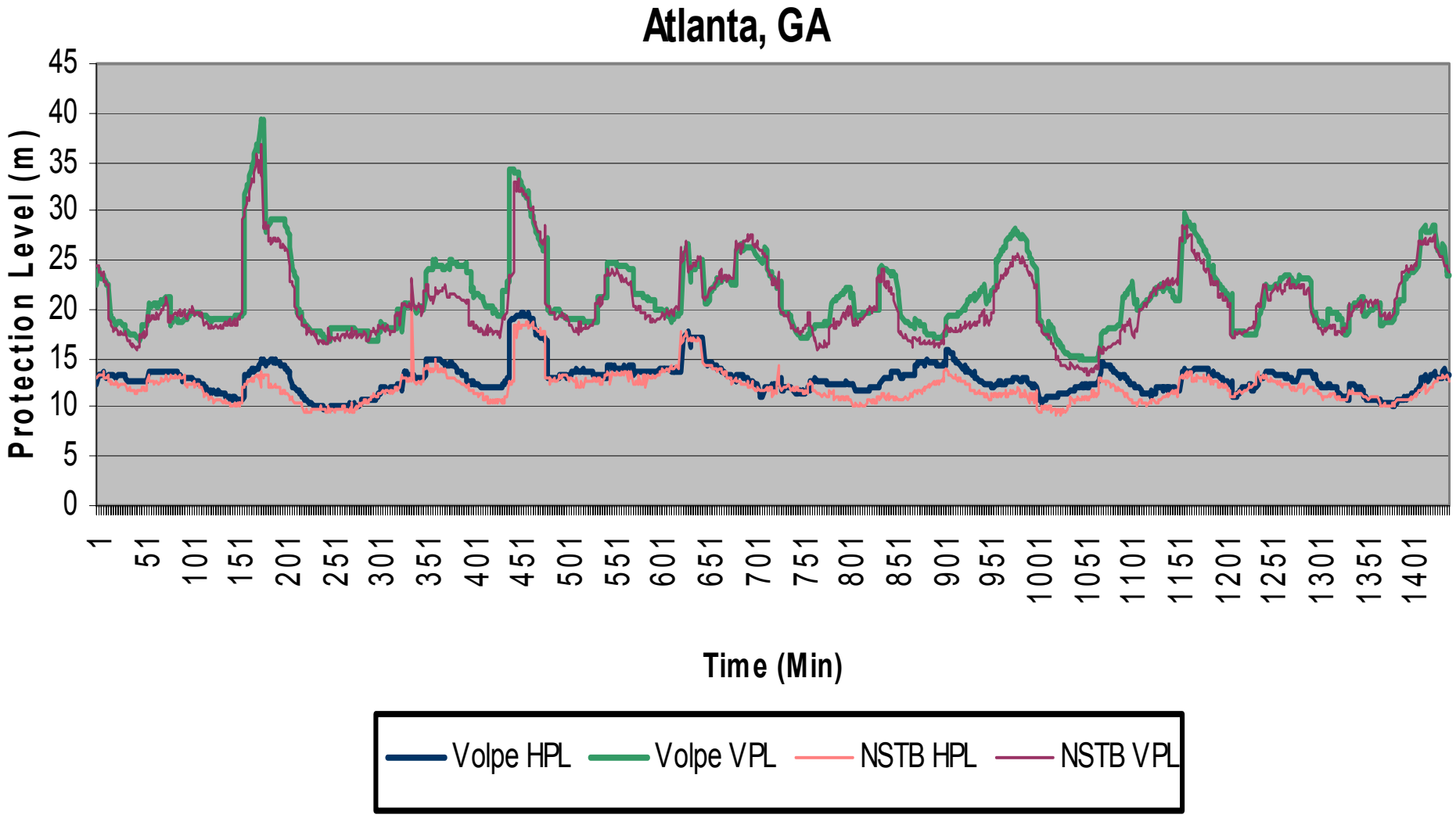
    HAL= 2.0 nmi
- **Approach Predictions**
  - Computed for Set of Airports at 1 Min.Time Intervals
  - Determine if HPL>HAL and VPL>VAL

    LNAV HAL=0.3 nmi

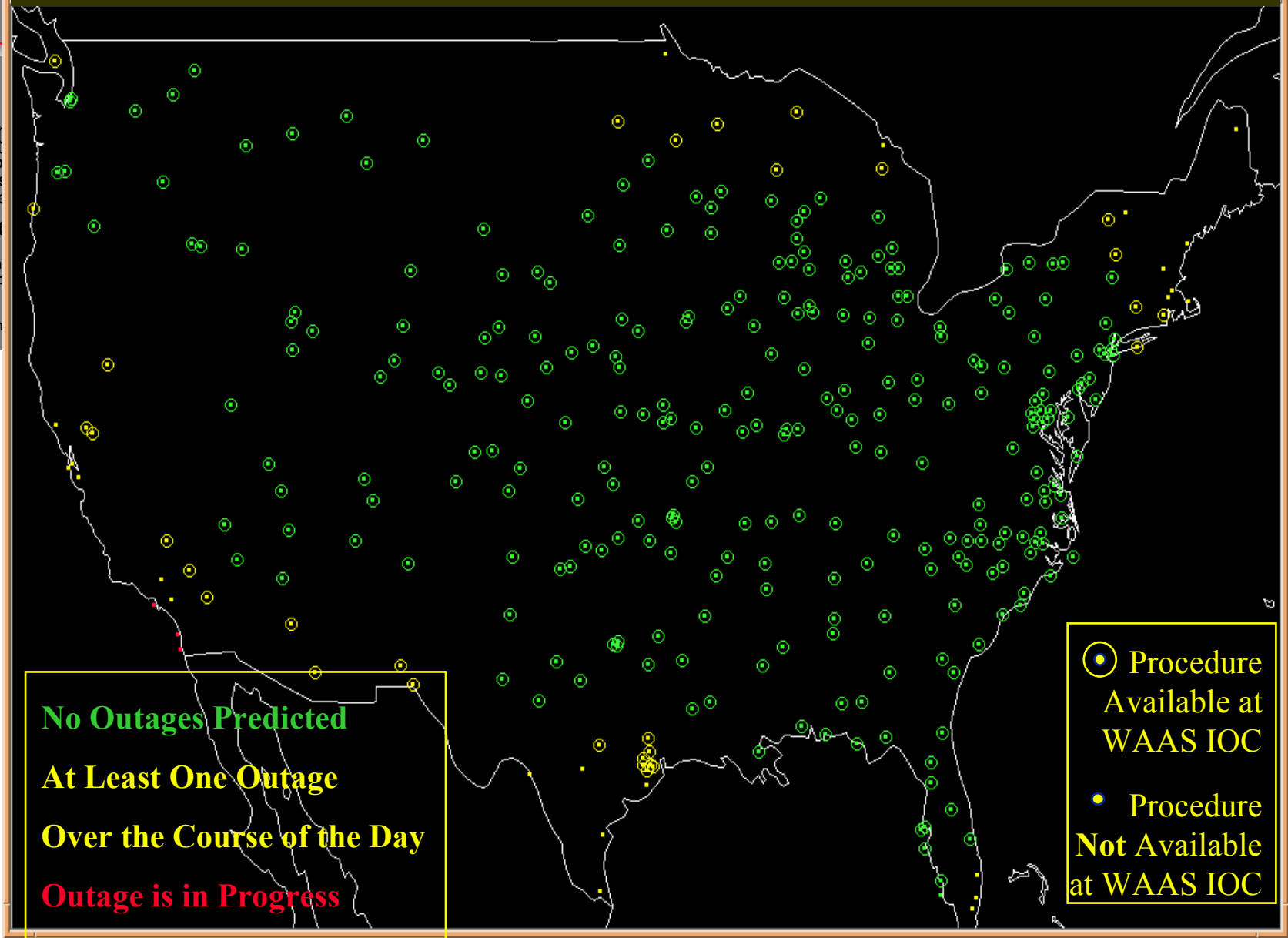
    LNAV/VNAV HAL=0.3 nmi VAL=50m

    LPV HAL=40m VAL=50m

WAAS Representative HPL/VPL Data



Airfield-Specific WAAS LNAV/VNAV Unavailability



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GPS Outage Prediction System - Dataflow

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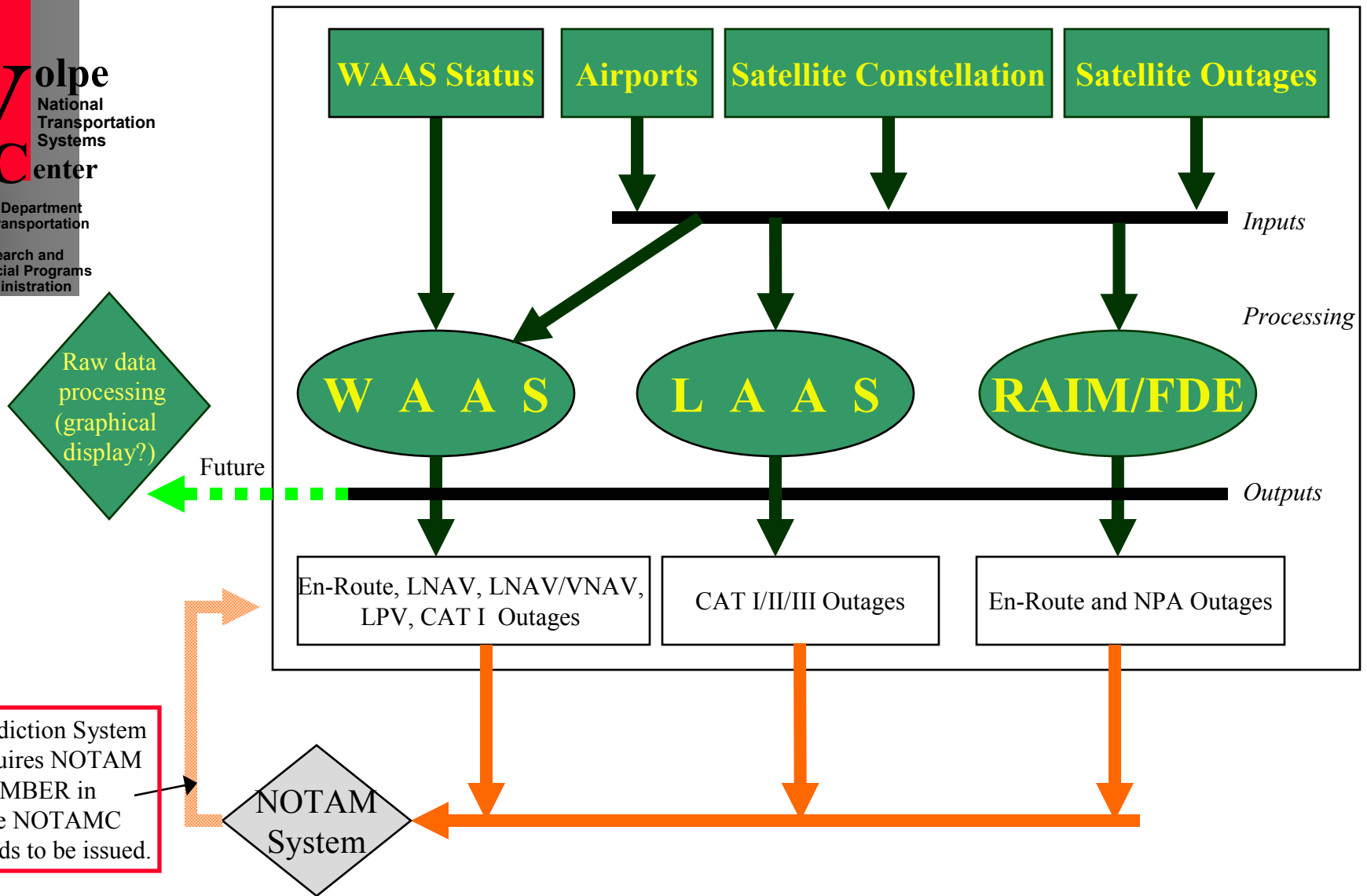

Challenges to the Prediction Capability

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- **Predicting Impact of Ionospheric Activity on GPS and Augmentation Systems is Non-Trivial**
  - How Long Does an 'Event' Last? Reacting to Iono Event May Produce NOTAMs Whose:
    - Duration Overbounds Actual Outage
    - Information That Changes Quicker Than User Can Process It
- **Short Duration Outages**
  - Should They Be Reported as NOTAM? How short?
  - Is There a Better Method for Reporting?
- **Hybrid Systems (e.g. GPS/INS, WAAS/EGNOS, GPS/Galileo, GPS/Galileo/GLONASS)**
  - Some Combinations Nearly Impossible to Predict
  - Will Pilot Know What Mix of Sensors Are OnBoard?

Challenges to the Outage Reporting Capability

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- Dissemination Of Outage Information That is More ***Accessible*** To Pilots (i.e. NOTAMS, DUATS, WEB-BASED)

- Dissemination Of Outage Information That is ***Meaningful*** To Pilots

  - Need to Distinguish Between Outage Information from Different Types of GPS Augmentation Systems and Hybrid Systems to Provide Meaningful Information to Pilots

Future Direction

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- **Incorporate Future Modifications to WAAS into Prediction Model**
  - Additional Ground Reference Stations
  - Additional GEOs
  - WAAS FOC 2007 (Refinements to Algorithm)
- **Develop and Validate LAAS Predictions**
- **Incorporate Graphical Interface Capability**
  - Data Fusion (e.g. Overlaying Regions of Weather, GPS Interference,etc.)
- **More Information Embedded or Sent Directly to Cockpit (Real or Near Real Time)**